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# Lecture 14 - Introduction to experimental work

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SDWED

# Introduction to Experiments

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PhD course
"Numerical and experimental modelling and control of Wave Energy Converters"

Tuesday 1 September 2015
Location: Ecole Centrale Nantes, Nantes, France

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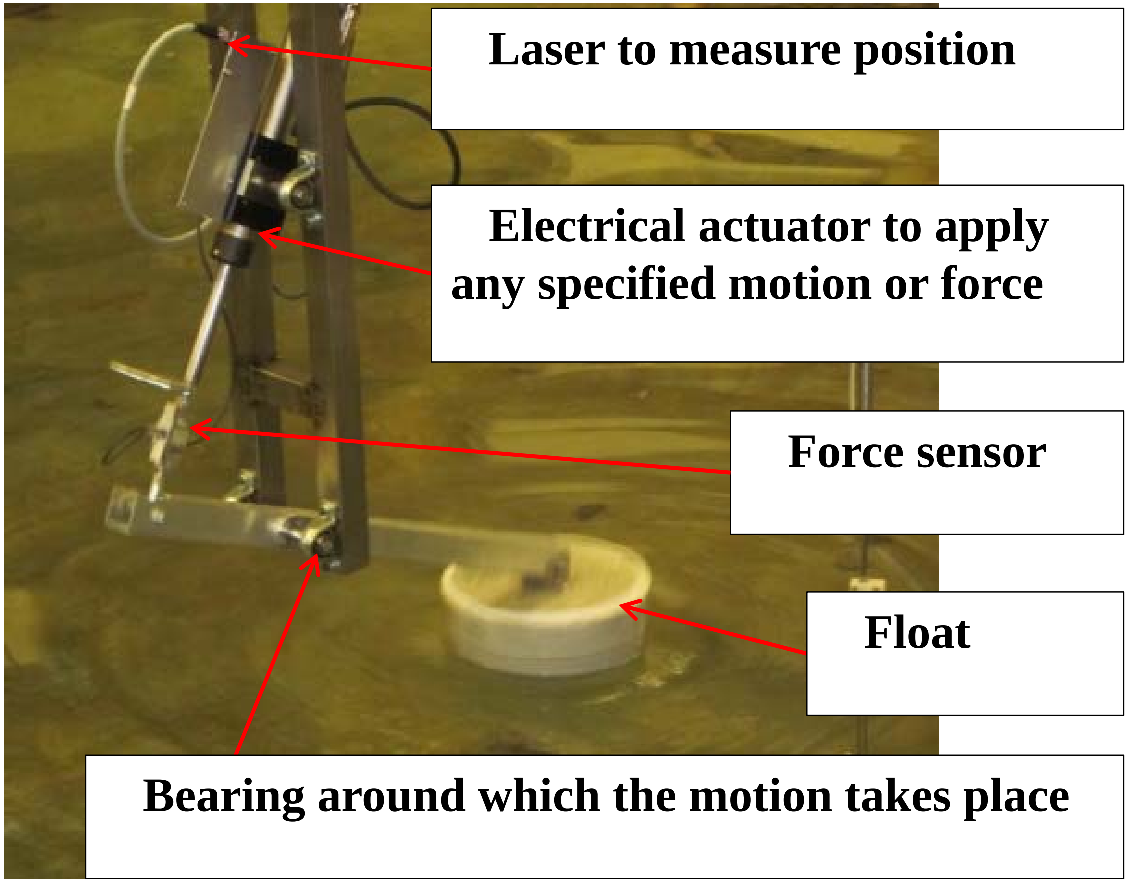
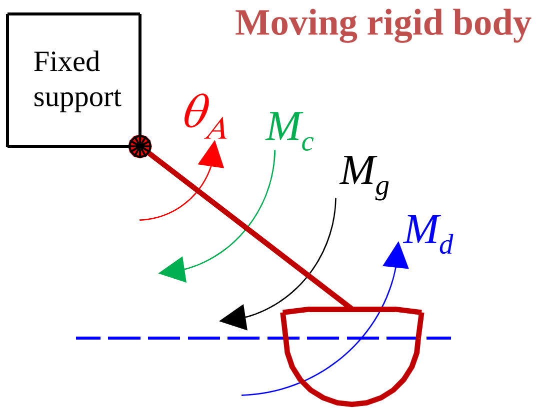
Department of Civil Engineering

WAVESTAR

# Laboratory test set-up of pivoting absorber



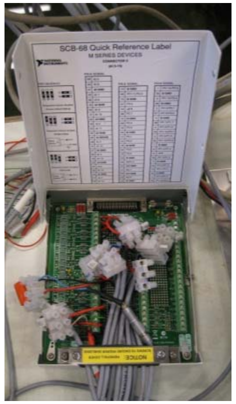

**Pivoting motions are described by rotations $\theta_A$.**

Newton's second law:

$$J\ddot{\theta}_A = M_d - M_g - M_c$$

$J$: Mass inertia moment of the moving body
$M_d$: Hydrodynamic moment
(from water pressure on hull)
$M_g$: Gravitational moment
$M_c$: Control moment from Power Take Off

# Control sketch




**Laptop** ···· **PC with xPc** — **NI DAQ** — **Linmot controller** — **Actuator**

**Laptop**

Simulink model. Model is compiled to C/C++ code and transferred to xPc before tests are executed.

**PC with xPc**

Online execution of control model and data acquisition.
The control model specifies the target force or position based on measured inputs from the NI DAQ.

**NI DAQ**

Data logger with inputs and outputs. One output for the Linmot controller is the target force or position.

**Linmot controller**

Hardware controller. Takes care of achieving the specified target position or force using position feedback from actuator or force feedback from external force sensor.

**Actuator**

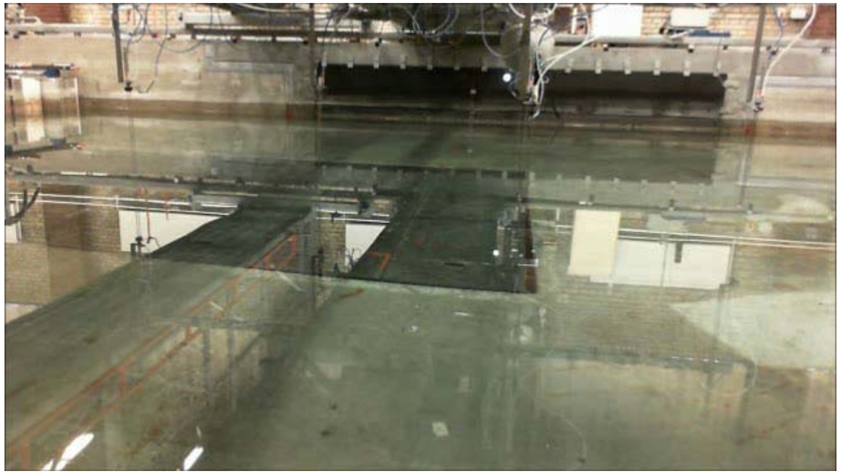
Linear motor (electrical cylinder). The linear motor consists of two parts: The fixed stator (tube) and the moveable slider (piston). An internal position encoder is included and used for position control.

# Waves in basin

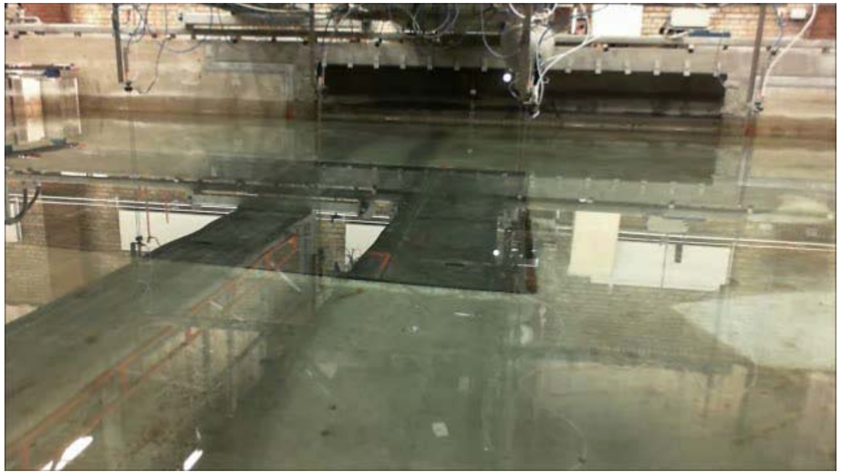
Waves are measured without the device in the basin.

Measured waves are considered as incoming waves (reflections from the beach and side walls are not taken into account).

Small wave

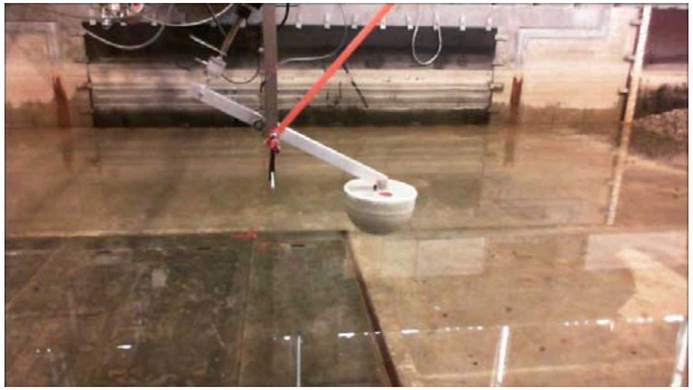


Large wave

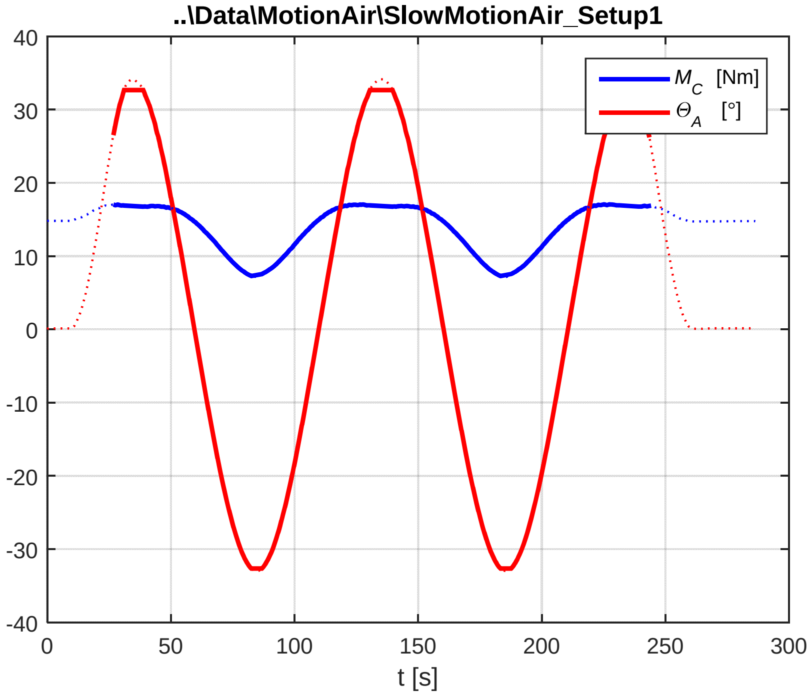


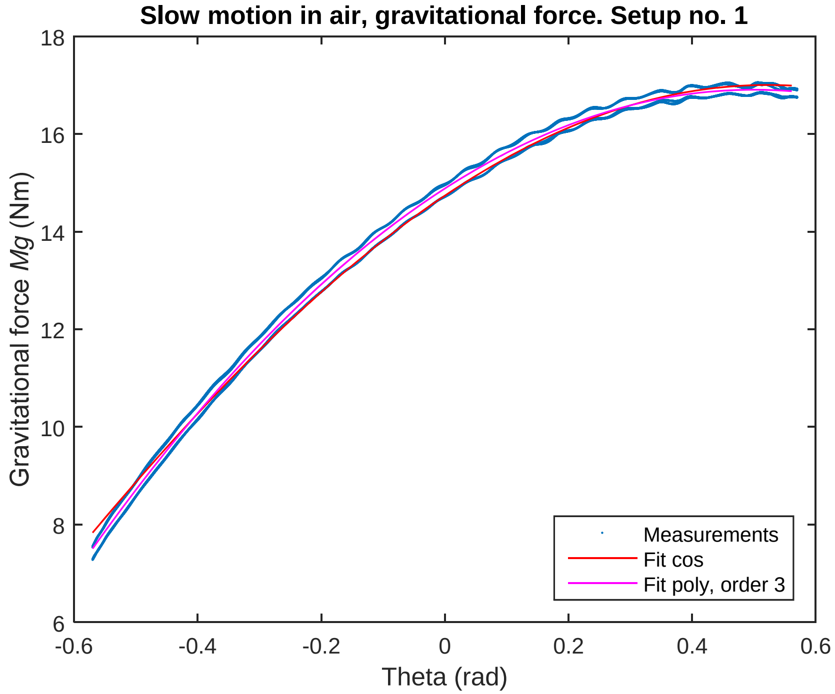
# Moment due to gravity

$$J\ddot{\theta}_A = M_d - M_g - M_c$$
$$\leftrightarrow \quad 0 = 0 \quad - M_g - M_c, \qquad \ddot{\theta}_A \cong M_d \cong 0$$
$$\leftrightarrow M_g = -M_c$$



Slow motion in air with sinus



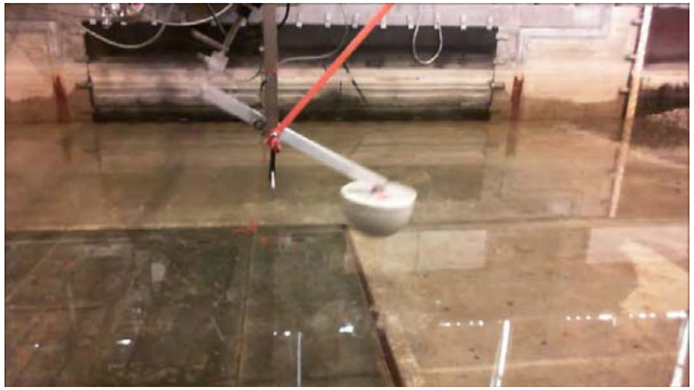
# Mass inertia moment

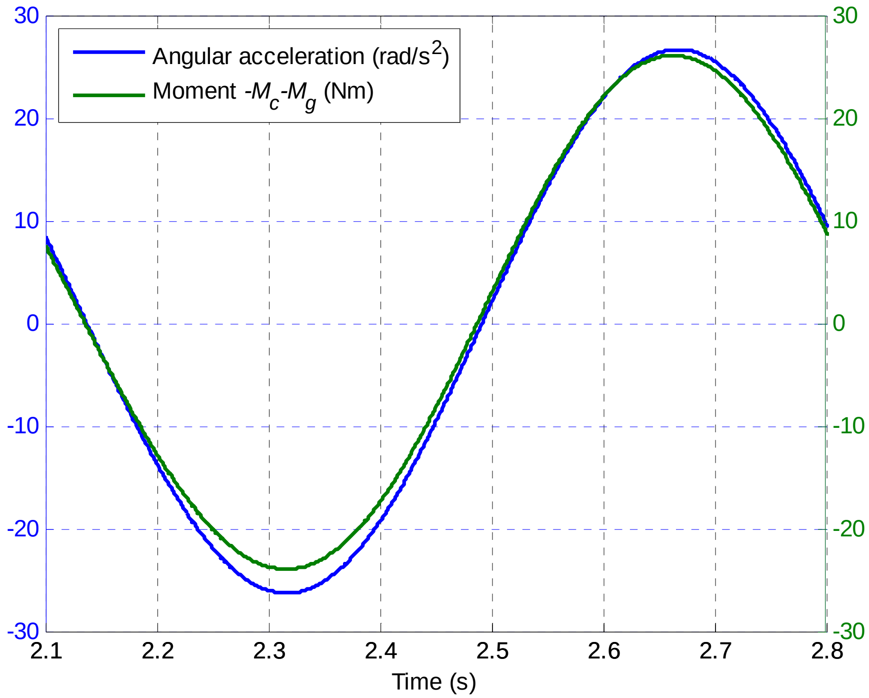
Accelerating motion in air

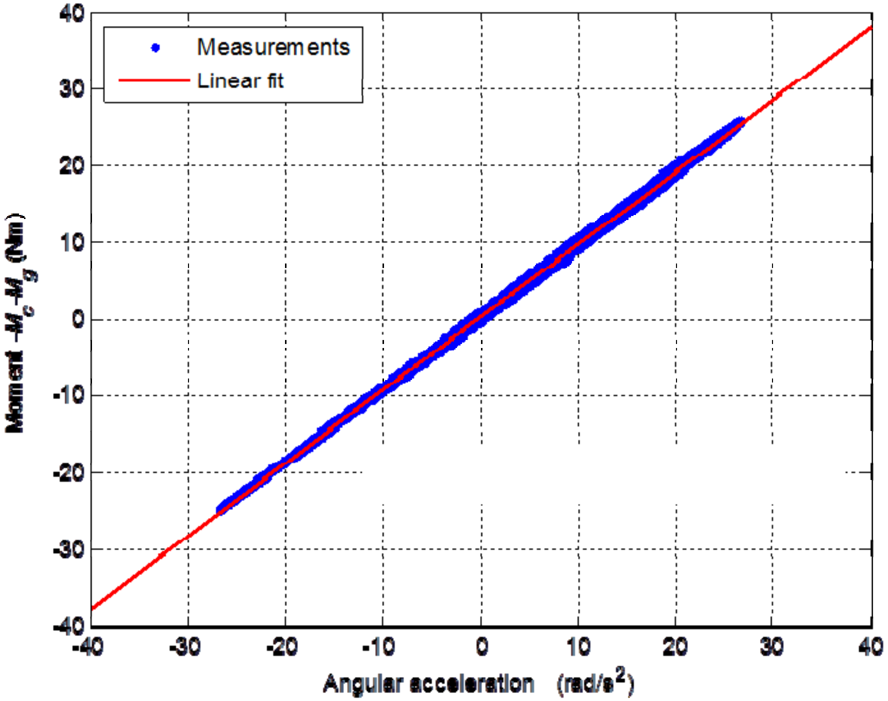
$$J\ddot{\theta}_A = M_d - M_g - M_c$$

$$\leftrightarrow \quad J\ddot{\theta}_A = 0 \quad - M_g - M_c, \qquad M_d = 0$$

$$\leftrightarrow -M_c - M_g = J\ddot{\theta}_A$$





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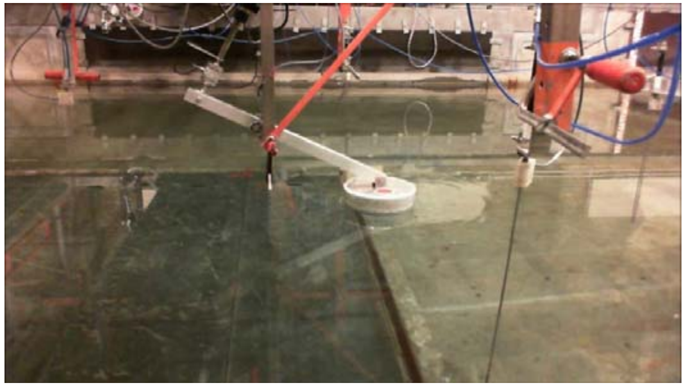
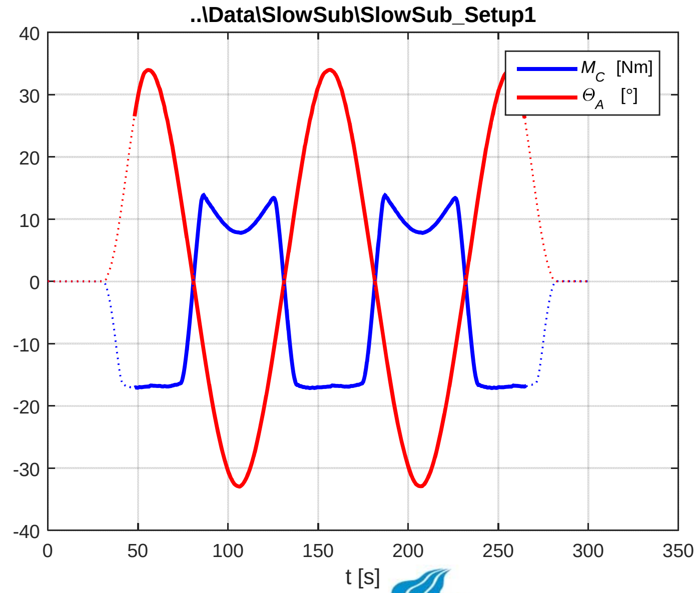
# Hydrostatic stiffness

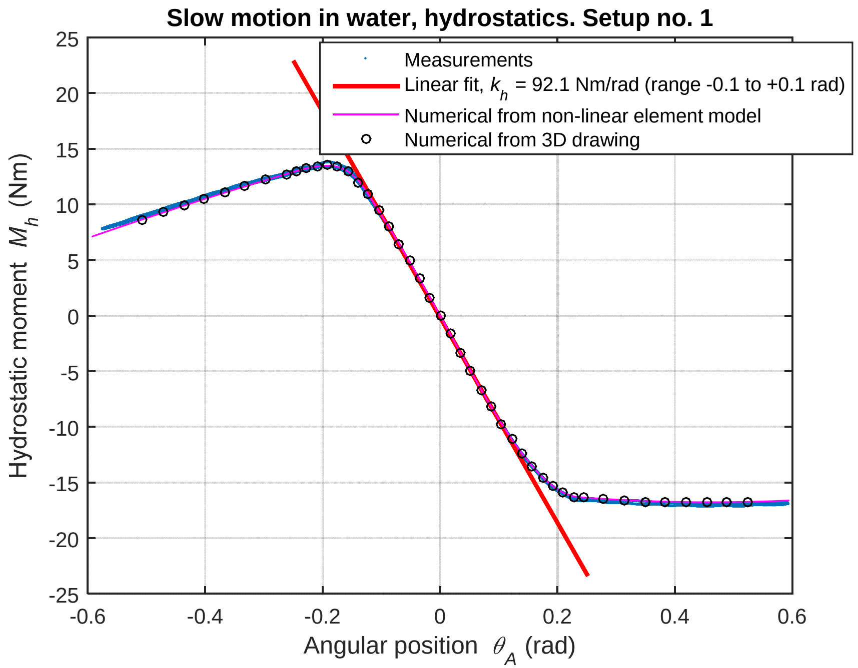
## Slow sinusoidal motion in calm water

$$
\begin{aligned}
& J\ddot{\theta}_A = M_{hs} + M_r + M_e - M_c \\
\leftrightarrow \quad & 0 = M_{hs} + 0 + 0 - M_c \qquad , \ddot{\theta}_A \cong \dot{\theta}_A \cong 0 \\
\leftrightarrow \quad & M_c = M_{hs}
\end{aligned}
$$

| | |
|---|---|
| Hydrostatic moment: | $M_{hs}$ |
| Radiation moment: | $M_r$ |
| Wave excitation moment: | $M_e$ |
| Control moment: | $M_c$ |



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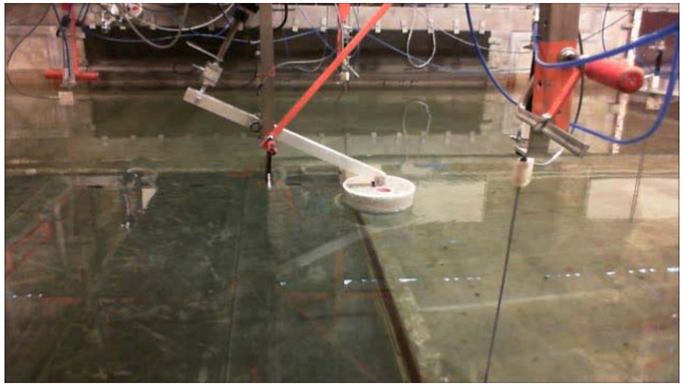
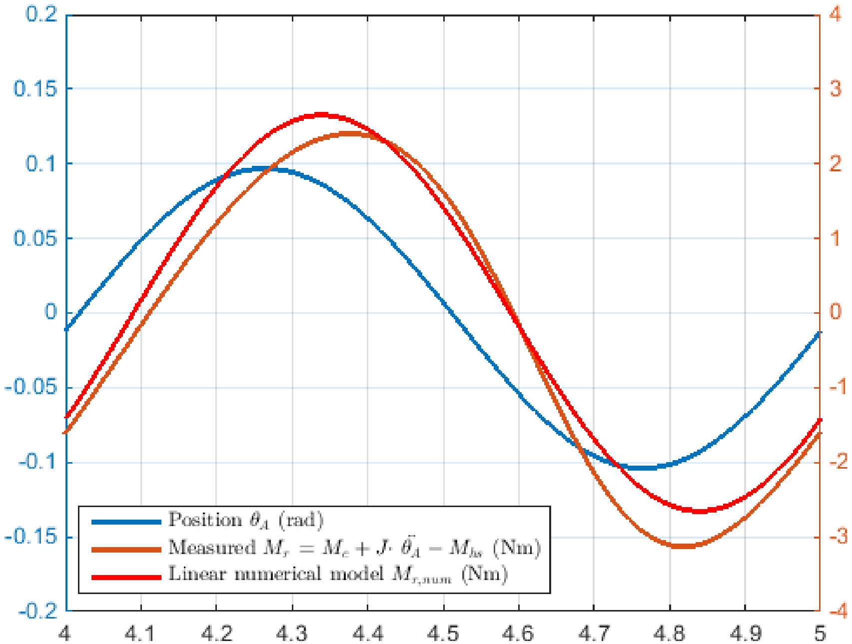
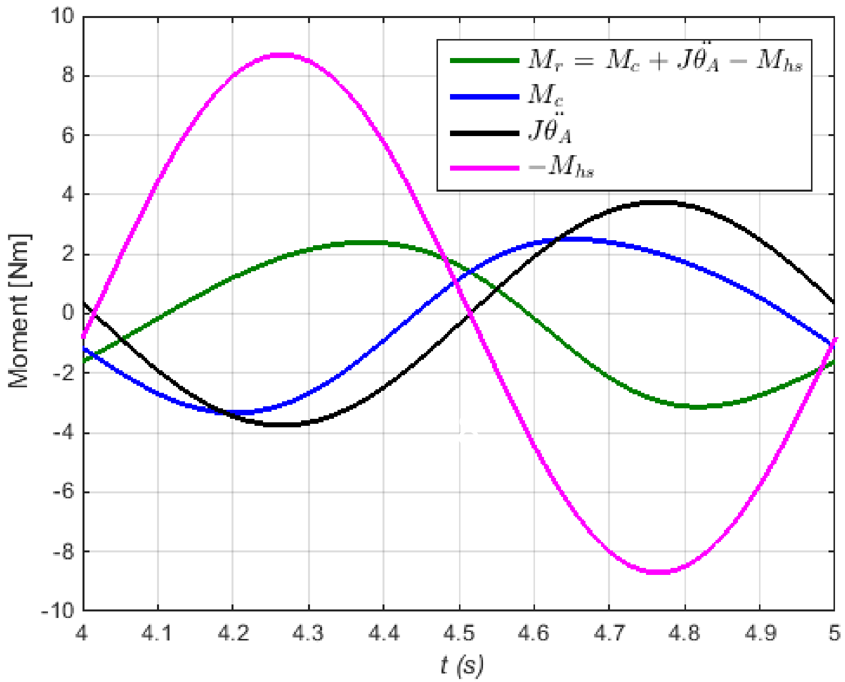
# Radiation force

Example figures with sinusoidal motion ($T$ = 1.0 s, motion amplitude = 0.1 rad)

$$J\ddot{\theta}_A = M_{hs} + M_r + M_e - M_c$$
$$\leftrightarrow\ J\ddot{\theta}_A = M_{hs} + M_r + 0 \quad - M_c \quad , \qquad M_e = 0$$
$$\leftrightarrow\ M_r = M_c + J\ddot{\theta}_A - M_{hs}$$



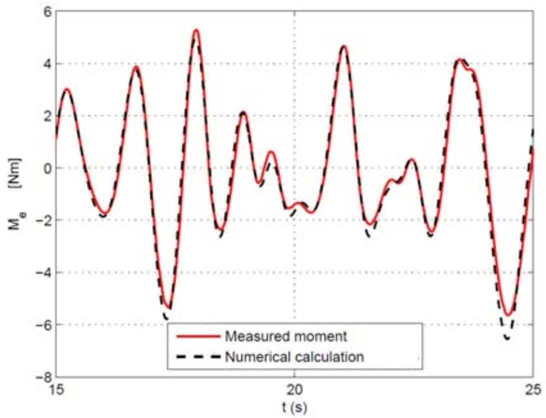


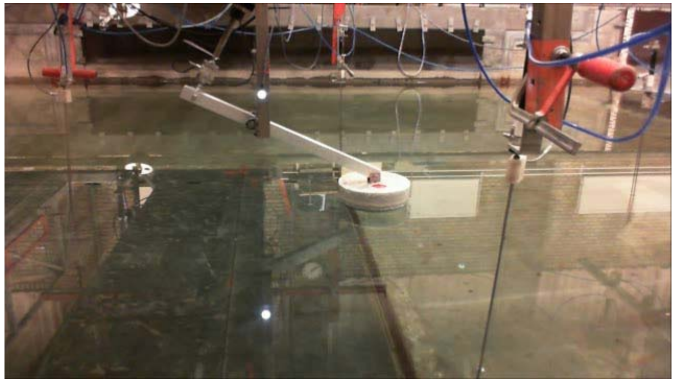



# Wave excitation force

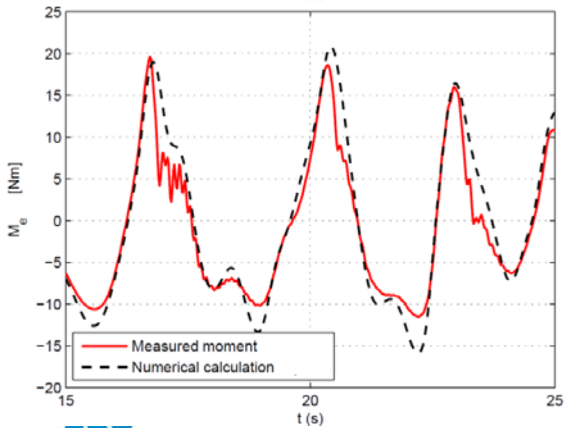
$$J\ddot{\theta}_A = M_{hs} + M_r + M_e - M_c$$
$$\leftrightarrow \quad 0 = 0 \quad + 0 \quad + M_e - M_c \quad , \ddot{\theta}_A \cong \dot{\theta}_A \cong \theta_A \cong 0$$
$$\leftrightarrow M_c = M_e$$

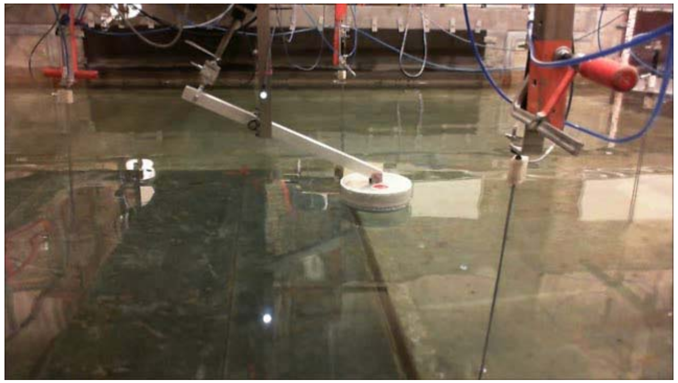
IRA4
$H_{m0,WG4} = 0.081\ m,\ T_P = 2.0\ s$



IRB5
$H_{m0,WG4} = 0.242\ m,\ T_P = 3.0\ s$



# Float in operation

Example with sea-state IRB1 ($H_{m0,WG4}$ = 0.051 m, $T_p$ = 1.0 s)